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SOUTHERN UTILIZATION RESEARCH AND DEVELOPMENT DIVISION

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PROGRAM AND ABSTRACTS OF PAPERS

TWELFTH CITRUS PROCESSING CONFERENCE

SOUTHEAST UTILIZATION RESEARCH AND DEVELOPMENT

C. H. Fisher, Director

U. S. Fruit and Vegetable Products Laboratory, Winter Haven, Florida

U. S. Fruit and Vegetable Products Laboratory, Washington, D. C.

October 3, 1962

WESTERN UTILIZATION RESEARCH AND DEVELOPMENT

Florida Room, Citrus Building  
Winter Haven, Florida

Fruit and Vegetable Chemistry Laboratory, Washington, D. C.

Western Regional Research Laboratory, Albany, Oregon

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IN

TWELFTH CITRUS PROCESSING CONFERENCE

October 3, 1962

MORNING SESSION - 9:30 A. M.

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U. S. Fruit and Vegetable Products Laboratory, Weslaco, Texas

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PROGRAM

CITRUS PROCESSING CONFERENCE

October 3, 1962

MORNING SESSION - 9:30 A. M.

(M. K. Veldhuis, In Charge, U. S. Fruit and Vegetable  
Products Laboratory, Winter Haven, Florida, Presiding)

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and Development Division, New Orleans, Louisiana, Presiding)

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## THE VOLATILE FLAVOR COMPOUNDS OF CELERY

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Winter Haven, Florida

In preliminary experiments on the flavor of celery, it was established that the compounds which impart this flavor are volatile, or at least volatile with steam. The total concentration of these compounds in celery juice was found to be on the order of 0.5 to 1 ppm, comprising 60 compounds. It was thus necessary to begin with large quantities of material. A total of about 10,000 pounds of celery was used in these studies.

The techniques used can be roughly divided into two categories: techniques dealing with separation and purification, and techniques dealing with identification.

Initial separation of the flavor compounds from celery was accomplished by vacuum distillation of the juice. The bunches of celery were separated into individual ribs, and these were steamed to inactivate enzymes. The juice was expressed in a hydraulic press, and distilled in a continuous pilot plant essence recovery unit. In this unit, the juice was flash vaporized under vacuum (ca. 25% vaporization). The condensate was given a second flash vaporization, and the liquid remaining after this second stage was fractionally distilled. Distillate was collected from the following portions of the apparatus: 1) column bottom (material accumulating in the distillation still-pot, 30 compounds); 2) chilled water trap (5 compounds); 3) ice trap (5 compounds); 4) salt-ice trap (6 compounds); 5) dry ice trap (23 compounds); 6) liquid nitrogen trap (5 compounds). This represented 60 different chemical substances.

Distillate (6) was a simple enough system to be separated directly by gas-liquid chromatography (GLC). Distillates (2), (3), and (4) contained relatively large amounts of water, and these were extracted with ether before being submitted to GLC. The complexity of distillates (1) and (5) required preliminary fractionation before GLC could be profitably employed. Distillate (1) presented an additional problem in that it consisted of approximately 100 liters of aqueous material, which, though smelling strongly of celery, was quite delute from a chemical standpoint. This material was concentrated by extraction with ether in a continuous counter-current liquid-liquid extractor, capable of extracting a 5 liter charge in about 4 hours. A total of 175 ml. of ether was used to extract the 100 liters of column bottoms.

Initial fractionation of both the column bottoms extract and the dry ice trap contents was based on functional group separation. Acids were removed with aqueous sodium bicarbonate, phenols with aqueous sodium hydroxide, aldehydes and ketones with Girard's T reagent (not used in the case of the dry ice trap), and hydrocarbons by silicic acid chromatography. The compounds within each of the classifications were then separated by GLC.





The remaining material was fractionated by silicic acid chromatography. Each of the eluted bands were separated by GLC.

It will be obvious that the fractionation procedures themselves furnish information useful in the identifications. The use of corrected GLC retention times as applied by Walsh and Merritt (Anal. Chem. 32:1378-81, 1960) and by Evans, Cooney and Panek (J. Amer. Oil Chem. Soc. 39:210-213, 1962) proved to be of great value, particularly in the early pinpointing of suspected compounds. A procedure was developed for evaluating column hold-up times, so that these techniques could be used with capillary columns and a flame ionization detector.

Because of the small quantity of material in the dry ice trap, additional information was gathered before the silicic acid fractionation, by the technique of subtractive GLC. An aliquot of the neutral material was treated with p-phenyl-azobenzoyl chloride to remove alcohols. The chromatogram (GLC) of the whole neutral fraction was compared with that of the alcohol-free material to determine which peaks were alcohols. Another aliquot was saponified, using a sealed tube microsaponification procedure. The chromatogram of the saponified material was compared with that of the whole neutral fraction to determine which peaks were due to esters. Acids were separated from the saponification mixture with aqueous sodium bicarbonate in order to determine which of the new peaks might be due to the acid residues and which to the alcohol.

Considerable use was made of Feigl's spot tests for functional groups (Spot Tests in Organic Analysis, Elsevier, 1956) for determining the types of compounds present in mixtures, as well as for characterizing purified compounds when sufficient quantities were not available for infrared spectrophotometry.

Most of the identifications (Table 1) are based on comparison of GLC retention times and infrared spectra with authentic materials. In the case of cis-3-hexen-1-yl pyruvate, identification is based upon retention time and infrared spectra of the saponification products. The identifications of carvyl acetate and neryl acetate are based upon retention time of the parent compound and the saponification products. Valeraldehyde, nonanal, and geranial, as well as the C-3, C-4, and C-8 through C-12 normal alcohols were identified by determining the functional group classifications and retention times. Sedanonic anhydride was identified through the preparation of the phthalazone with hydrazine hydrate.

Since neither of the dihydrophthalides listed in table 1 have appeared in the literature before, it was necessary to characterize these compounds using the following techniques: 1) I. R., U. V., and mass spectrometry; 2) ozonolysis; 3) saponification and relactonization; and 4) aromatization and comparison with the synthetic aromatic materials.

While most of the compounds listed probably make some contribution to the overall flavor and odor, the compounds of particular importance from this standpoint are the phthalide derivatives plus cis-3-hexen-1-yl pyruvate and diacetyl.





Table 1

Compounds Identified From Celery

<u>Acids</u>	<u>Hydrocarbons</u>	<u>Ketone</u>	<u>Phenol</u>
acetic	d-limonene	carvone	guaiacol
n-valeric	myrcene		
iso-butyric			
pyruvic			

<u>Aldehydes</u>	<u>Esters</u>	<u>Alcohols</u>
formaldehyde	ethyl isovalerate	propanol
acetaldehyde	cis-3-hexen-1-yl pyruvate	butanol
propionaldehyde	decyl acetate	iso-amyl
valeraldehyde	linalyl acetate	hexanol
hexanal	terpinyl acetate	heptanol
heptanal	geranyl acetate	octanol
octanal	citronellyl acetate	nonanol
nonanal	neryl acetate	decanol
undecanal	carvyl acetate	undecanol
dodecanal	terpinyl propionate	dodecanol
neral	geranyl butyrate	
geranial	benzoyl benzoate	
citronellal		
diacetyl		

<u>Phthalides</u>	<u>Suspected Compounds</u>
3-isobutylidene phthalide	2-methyl hexanyl acetate
3-isovalidene phthalide	palmitic acid
3-isobutylidene- $\triangle^{5,7}$ -dihydrophthalide	branched C-7 acid
3-isovalidene- $\triangle^{5,7}$ -dihydrophthalide	branched C-8 acid
	7 compounds unidentified
sedanonic anhydride	

Publication:

TECHNIQUES IN THE ISOLATION OF VOLATILE MATERIALS FROM CELERY AND THE IDENTIFICATION OF SOME COMPOUNDS WITH ACIDIC PROPERTIES.

Gold, Harvey J., and Wilson, Charles W. III.

Fla. State Hort Soc. 74, 291-296 (1961).



# SHELF LIFE OF CHILLED ORANGE JUICE WITH HEAT TREATMENT AND PRESERVATIVES

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It has been reported by Robinson and Hills (1) that sodium sorbate and mild heat increased the shelf life of citrus sections. The present investigation was undertaken to determine if this was also true for chilled juice. Benzoate was included for comparison and because of its effectiveness against a wide range of organisms.

Chilled orange juice was packed in December, January, and April, and stored at 30 and 40° F. Control samples for the first two packs were stored at 0° F. and the last at -90° F. The packs were treated with .033% benzoate or sorbate and 120, 140, or 160° F. heat treatments with 3 and 5 minute holding times at those temperatures. Controls were packed with no heat treatments and no preservatives. Shelf life was considered to be the time required to obtain a highly significant difference between the experimental sample and its control in 24 flavor judgments by the triangular method. The taste panel controls differed from their experimental samples only in the storage temperature used. Plate counts, cloud, and ascorbic acid determinations were also made.

Plate counts increased only in the samples with no preservatives, none and 120° F. heat treatment and stored at 40° F. Results from the cloud determinations were inconclusive, but the trend was toward greater cloud stability as the heat treatment was increased. Preservatives apparently had no effect on cloud. Ascorbic acid decreased as the temperature of storage increased and as the time in storage progressed.

The effects of several variables on the shelf life of a typical series of packs is presented in the table.

Storage life in weeks -		Valencia orange juice			
Preserv- ative	Heat treat- ment (°F.)	Hold time (minutes)			
		3		5	
		Storage temperature (°F.)			
		30	40	30	40
None	None	4	2	5	2
	120	9	6	10	6
	140	12	8	12	8
	160	13	9	13	9
Benzoate	None	6	4	7	4
	120	11	7	11	8
	140	13	9	13	9
	160	13	10	14	10
Sorbate	None	7	3	7	3
	120	11	6	11	6
	140	13	9	13	9
	160	13	10	14	10





Preliminary investigations involving the use of Vitamin K<sub>5</sub> as a preservative indicate that 50 ppm is effective as an antimicrobial. However, ascorbic acid assays reveal a rapid drop in ascorbic acid content in the presence of this vitamin.

1. Robinson, James F., and Hills, Claude H. Preservation of fruit products by sodium sorbate and mild heat. Food technol. (1959) Vol. XIII(5) pg. 251-53.



SOME ASPECTS OF THE CHEMISTRY  
OF THE BITTER PRINCIPLES IN CITRUS FRUITS

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Navel oranges grown in California are seldom used for processing because the extracted juice becomes bitter and unpalatable when heated or exposed to air for even a few hours. Intensity of the bitterness is largely dependent upon the maturity of the fruit, being most pronounced in juices from early season fruit and varying from season to season. The long standing problem of navel juice bitterness will be reviewed and the chemical aspects discussed. The known compounds responsible for navel bitterness will be described and particularly the unique reactions of limonin, the major bitter constituent, which hold some promise of being used in the development of a practical process for debittering the juice. For example, limonin may be converted by air oxidation with a sensitizer to give the non-bitter limonexic acid.

Enzymes have been tested in bitter navel juice as one approach to a solution of the debittering problem. Extensive cloud loss occurs with many of the commercial enzyme preparations tested to date and any decrease in bitterness of the juice appears to parallel the degree of cloud loss. This raises the question, first suggested by McColloch of our laboratory, that the enzyme preparation may cause a breakdown of the colloidal state of the system resulting in a shift of limonin from the colloidal phase to the insoluble-solids phase to bring about a decrease in bitterness. In this case, debittering might well be a physical instead of a chemical mechanism.

The biosynthesis from euphol and the botanical distribution in nature of the triterpenoid bitter materials (nimbin, swietenolide, gedunin, cedrelone, khivorin, swietenin, limonin, obacunone, and nomilin) will be outlined.





## CARBONYL ANALYSIS OF COLD-PRESSED ORANGE OIL

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A progress report on the work on carbonyls is presented. The effects of carbonyl constituents on cold-pressed orange and flavor are recognizably important. It was desirable to isolate and identify these constituents without rearrangement or artifact formation. Cold-pressed orange oil was treated with silica gel and the terpenes removed with n-hexane according to established procedures. The adsorbed terpenoids were then removed with isopropanol. The residue following removal of the solvent was treated with Girard-T reagent and the carbonyls isolated as salts were regenerated with formaldehyde. During this work it was observed that artifacts were introduced into the system traceable to impurities in the formalin solution, however, extraction of the formalin solution prior to use with isopentane removed the extraneous materials. The use of isopropanol or tert-butanol for the extraction of the regenerated carbonyls precluded the formation of acetals.

The regenerated carbonyls were further separated by gas chromatography and the material from the individual peaks analyzed by infrared spectroscopy. The analysis showed the presence of n-octanal, n-nonanal, rhodinal, citronellal, n-decanal, n-undecanal, neral, geranial, n-dodecanal, and carvone. Alpha-terpineol continually appeared as a contaminant. Many of these compounds have been previously reported by other investigators, however, rhodinal is reported here for the first time to be a constituent of orange oil.

It was observed that the citronellal concentration decreased noticeably when using large silica gel columns during the initial deterpination step. It has subsequently been shown that citronellal readily isomerized to isopulegol by cyclization on silica gel. Isopulegol had been found in the analysis products whenever the citronellal concentration was low. It was further observed that preparatory gas chromatographic columns containing Carbowax 20M also isomerized citronellal to isopulegol, however, capillary columns containing this substrate did not promote this isomerization. Isopulegol was found to be quite stable and did not undergo further isomerization or give dehydrated products under these mild conditions.

It is entirely feasible to utilize the established procedures discussed above for the analysis of carbonyls providing precautions are taken to prevent the formation of artifacts. Silica gel free of alumina at low temperatures will not readily promote isomerization. Analysis of these carbonyls should be carried out on capillary columns which require lower operating temperatures.



## TERPENE ANALYSIS OF COLD-PRESSED ORANGE OIL

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In order to study the effects of various processing parameters on orange product flavor it was necessary to elucidate the chemical composition of cold-pressed orange oil. The established reported procedures were used for the separation of terpenes from the terpenoids present in the whole oil. Cold-pressed orange oil was treated with silica gel and the terpene fraction, eluted with hexane, was stripped of solvent and rectified. The fractions appearing before and following d-limonene were further separated by gas chromatography to reveal the presence of 15 terpenes. The individual peaks were collected from a preparative-scale gas chromatograph and analyzed by infrared spectroscopy. Twelve constituents were identified as alpha-thujene, alpha-pinene, camphene, sabinene, myrcene, delta-3-carene, alpha-phellandrene, alpha-terpinene, d-limonene, gamma-terpinene, p-cymene and terpinolene. The remaining three terpene infrared spectra have been obtained and are in the process of structural elucidation.

During this work it was observed that isomerization and disproportionation took place on large silica gel columns while deterpenating substantial quantities of oil. Investigations toward the identification of these artifact precursors required the analysis of the individual terpene products after treatment with silica gel. It was observed that under these conditions d-limonene isomerized to alpha-terpinene, gamma-terpinene, p-cymene, and terpinolene. Under more vigorous conditions l-p-menthene, t-2-p-menthene, 3-p-menthene, t-8(9)-p-menthene and p-cymene were found. It was also observed that p-cymene dimerized to 1,3,3,6-tetramethyl-1-p-tolylylinden. The remaining p-menthadienes were treated with silica gel to give the same products as d-limonene including dipentene. Since these p-menthadienes isomerized to give only those found in the original oil, it is entirely feasible to assume d-limonene to be the major precursor to these particular p-menthadienes.

Myrcene, a terpene constituent of orange oil, also underwent isomerization on silica gel to give the compounds described above in addition to ocimene and alpha-phellandrene.

The bicyclic terpenes found to be constituents of orange oil were isomerized on silica gel at elevated temperatures. Alpha-pinene yielded camphene, alpha-terpinene, dipentene, gamma-terpinene, terpinolene and isoterpinolene. These disproportionated to give the products described above. Camphene isomerized to tricyclene. The data shows that sabinene isomerized to alpha-thujene which gave the products observed for alpha-pinene except camphene and in addition afforded alpha and beta-phellandrene. Delta-3-carene isomerized to delta-4-carene, alpha and gamma-terpinene, isoterpinolene and m-menthadienes. These, too, disproportionated to p-menthenes, p-cymene and m-cymene.







These results indicate that d-limonene could possibly be the precursor to some of the p-menthadienes found in orange oil. The presence of camphene in the oil also appears to be an acid catalyzed isomerization product from alpha-pinene. The presence of alpha-phellandrene could be traced to the acid catalyzed cyclization of myrcene which is a product of dehydration under these conditions. It is hoped that the precursors to all of the orange oil constituents can be elucidated in this way, thus providing an understanding of the changes in flavor.



## SOME ENGINEERING ASPECTS OF THE FOAM DRYING OF DAIRY PRODUCTS

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Spray drying of milk and milk products is the accepted method of dehydration. Last year, over 2 billion pounds of nonfat dry milk, 26 million pounds of dry whole milk and considerable amounts of other dehydrated products such as sweet whey and buttermilk were produced.

More than 4 billion pounds of cottage cheese whey is being produced annually and production is increasing. It has always been a problem, especially when it is dumped into a waste disposal system. In some localities plants have been forced to shut down because of legal restrictions on whey disposal.

Some cottage cheese whey is being dried with additives such as nonfat milk and cereal products.

Gas-injection spray drying has been used recently in drying whole milk, nonfat milk, cottage cheese whey, cheddar cheese and blue cheese. In all instances a superior product has been obtained.

With this method and concentrates containing about 60% solids, dryer capacity has increased over 100%. Whole milk and nonfat milk powders are "instantized" by this method. Cottage cheese whey is easily dried in a form readily handled for shipment.

We believe that the production of better dry milks and dehydrated dairy products with a saving in processing costs will result in increased consumption of milk and thus help to decrease surpluses.

(Note: This represents cooperative work between the Winter Haven Laboratory and the Eastern Research Division who do work on spray drying of milk. It is of course possible that some of the techniques used on milk will apply to citrus juices.)





## PRESENT STATUS OF FOAM-MAT DRYING

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Foam-mat drying produces good instant powders from liquid foods cheaply. It consists of air drying thin pieces of stiff foams made from the food or food concentrate. An edible foam stabilizer is often used with the food to insure that the foam does not collapse early in the drying operation.

Continuous commercial-scale foam-mat drying equipment is now being offered for sale by three U. S. manufacturers. Two large production dryers have been installed, one mainly for tomato paste and one for baby foods. A third large unit is available for testing. Six continuous automatic pilot plants are in use in this country. Several pilot dryers without automated feeding and collecting have also been completed. Development of citrus powders by foam-mat drying is underway in Europe in a pilot plant there.

Several methods of spreading out the foam thinly for drying are in use. In one case, the foam is laid on a belt which carries it through warm air streams flowing across the food while heat is applied to the bottom of the belt. The foam can be a thin layer covering the belt or a number of thin extrusions lying near each other. A somewhat thicker layer, however, may be laid on perforated trays. The foam layer may be pierced by air jets and the trays may be stacked in a through-flowing column of warm air. Both types of equipment are being offered commercially.

Orange powder has been produced by both variations during the last year in our laboratories. When properly operated, juice quality by each method is high. Much higher production can be achieved with through-flow (crater) for a dryer of a given cubic volume. If quality can be maintained, however, very thin layers can be dried on a belt in 1 to 3 minutes, resulting in still high production rates. The tray concept is probably limited to 200 lbs. of powder per hour per unit, whereas the belt may be as long as desired.

The color and density of the orange powder have been improved by flaking the pieces of dry foam between warm rolls. This considerably improves reconstitution in ice water.

Finish drying of orange powder is still under scrutiny. Unfortunately, extractive drying by alcohol is not possible for orange powders. Only methanol is adequately effective as a substitute for in-package-desiccation, and removal of traces of the alcohol is difficult.

A number of companies have cooperated with the Albany laboratory in the application of foam-mat drying to their own commodities. This program continues, together with the flavor concentration and restoration aspects of food drying.





FOAM-MAT DRYING -- FURTHER STUDIES ON DRYING METHODS  
AND FLAVOR STABILITY OF ORANGE JUICE POWDER

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In previous reports on foam-mat drying, the methods of foam preparation, the principle and operation of the dryer, and some early drying studies were discussed.

Recent refinements in equipment permit more closely controlled operating conditions, higher air temperatures in the initial section of the dryer than previously, and a more uniform rate of application of foams to the belt traveling through the dryer.

The dryer is now divided into five rather than the original four controlled temperature zones or sections so that now air temperatures as high as 260° F. may be used in the first section. Temperatures are then scaled downward to 160° F. in the last section. The required air temperature in each section of the dryer, to effect a desired foam temperature during drying, is subject to several variables such as belt speed and loading rate, foam density and variations in characteristics of the concentrates being dried. The dried product is removed from the belt in a room maintained at a low relative humidity.

The dry room was maintained at 10 to 12% relative humidity since we have shown that at the 85° F. in the dry room a relative humidity of 15% was required to be in equilibrium with powder of 2.5 to 3% moisture content as it came from the dryer. The 10 to 12% level provided a measure of safety.

Experiments were conducted to determine the effect of times and temperatures during drying on the rate of moisture removal, final moisture content, and evaluation of the products for ascorbic acid, total acidity, color change and flavor. A record of the foam temperature during drying was obtained by use of a "traveling" thermocouple imbedded in the foam, and samples were removed from each section of the dryer to determine moisture removal to that point. Six experimental powders were prepared at a foam temperature of 160° F. with duration of drying varying from 11.7 to 26.2 minutes. Five powders were dried at foam temperatures of 170° F. with time varying from 10.5 to 17.5 minutes and seven were dried at 180° F. with drying time varying from 8.8 to 17.5 minutes. In addition a reference powder of good flavor quality was prepared for use in evaluating flavors of the experimental products. The results showed that high initial air temperatures promoted rapid removal of moisture from the foams and as foam temperatures rose air temperatures in succeeding sections of the dryer were reduced to avoid excessive product temperature. The desired foam drying temperatures were reached in about seven minutes and maintained in a satisfactory manner for the duration of drying. Foams lost moisture throughout the drying period, however, the rate of removal decreased as drying progressed. The higher the foam drying temperature the more rapid the





moisture removal. Also, as duration of drying increased at any given drying temperature the final product moisture decreased.

None of the powders dried at 160° F. were found different in flavor from that of the control. This was also true of products dried at 170° and 180° F. for periods of 13 minutes or less. Drying for longer periods at these two latter temperatures resulted in products differing in flavor from the controls at the 5% level of significance.

While there was no change in ascorbic acid content of the products due to processing there was a slight increase in total acid and a slight increase in color of clarified serums of reconstituted juices as indicated by the colorimeter. These color differences were not, however, visually apparent.

The data indicates that foam temperatures up to about 180° F. can be used in foam-mat drying of orange juice. Increasing the air temperature in the first part of the dryer permitted rapid attainment of 180° F. foam temperature and the production of a dried product in as short a time as 10 to 13 minutes without damage to flavor or other quality characteristics.

(Note: This represents cooperative investigations of the Florida Citrus Commission and the Southern and Western Utilization Research and Development Divisions.)



USE OF DEBITTERED GRAPEFRUIT JUICE AS A BASE  
FOR FRUIT AND BERRY FLAVORED PUNCHES AND DRINKS

B. J. LIME, F. P. GRIFFITHS, and D. M. TUCKER  
U. S. Fruit and Vegetable Products Laboratory  
Weslaco, Texas

The enzymatic debittering of grapefruit juice increased its flavor compatibility with such flavors as strawberry and raspberry. Debittering made it possible to increase the quantity of grapefruit juice in the juice blends and drink bases. Highly acceptable drinks were prepared with partially and completely debittered grapefruit juice blended with juice or puree from such fruits and berries as orange, strawberry, raspberry, blackberry, and plum.

A series of orange-strawberry flavored grapefruit drinks was prepared by using as the grapefruit portion, debittered grapefruit juice, partially debittered grapefruit juice, and normal grapefruit juice. Another series was prepared from partially debittered grapefruit juice with sugar contents of 10, 13 and 16 percent with constant acid and with acid contents of .50, .70 and .90 with the sugar content constant. These juices were used in determining the preference of two taste panels for levels of bitterness, acid and sugar. One panel was composed of 51 adults and the other was composed of 25 seven-year-old children. Eighty-six percent of the adults tested preferred no, or medium, bitterness, while 68 percent of the children preferred no, or medium, bitterness. Twenty percent of the adult panel and 32 percent of the children's panel preferred the low acid drink, while 39 percent of the adults and 28 percent of the children preferred the middle acid drink. Sixty percent of the children and 35 percent of the adults tested indicated a preference for the high sugar drink, and 20 percent of the children and 49 percent of the adults preferred the middle sugar level drink. While 25 percent more of the children preferred the sweeter drink, the adults and children showed the same preference for the higher acid drink.

A triangle taste panel composed of 14 adult members was used to examine the effect of pH upon the taste perception of sweet and sour flavor of partially debittered grapefruit based drinks. With the sugar level constant, the panel could detect a difference of 0.15 percent acid, which was statistically significant. With the acid level constant, a difference of 1.5 percent sugar was significant. When the acid and sugar levels were constant, a change of 0.2 in pH could be detected on a significant level. A difference of 0.2 percent acid could be compensated for by increasing the pH of the high acid drink to 0.3 more than the pH of the low acid drink, as indicated by the taste panel when it failed to detect a difference on a significant level between the two drinks.





UNITED STATES DEPARTMENT OF AGRICULTURE  
AGRICULTURAL RESEARCH SERVICE

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AND PATENTS

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SOUTHERN UTILIZATION RESEARCH AND DEVELOPMENT DIVISION

U. S. FRUIT AND VEGETABLE PRODUCTS LABORATORY  
600 Avenue S, N. W.  
Winter Haven, Florida

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1/ Patents can be obtained only by purchase from the U. S. Patent Office,  
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U. S. FRUIT AND VEGETABLE PRODUCTS LABORATORY  
Weslaco, Texas

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FRUIT AND VEGETABLE CHEMISTRY LABORATORY

263 South Chester Avenue  
Pasadena 5, California

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800 Buchanan Street

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1/ Patents can be obtained only by purchase from the U. S. Patent Office, Washington 25, D. C., for 25 cents each.

Reprints of the above-listed publications are available and may be obtained without cost by addressing request to the laboratory.

